NASA TECH BRIEF
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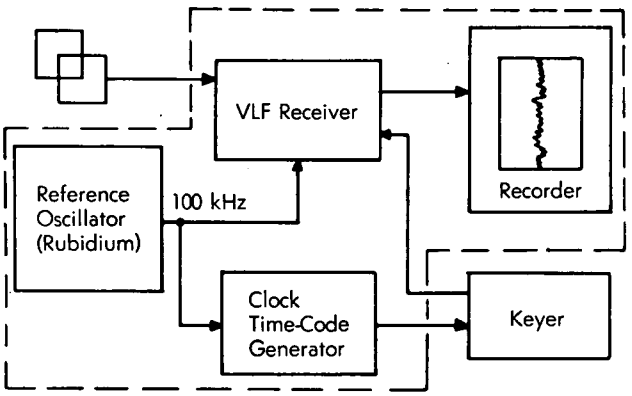
Time-Synchronized VLF Phase-Tracking Receiver

Coded signals transmitted at very low frequencies (VLF) by the National Bureau of Standards via its radio facility WWVL contain both primary time and frequency information. The transmitted information is in three-frequency format, 19.9, 20.0, and 20.9 kHz; transmission of a given frequency takes place over an exact 10-second interval. The frequency sequence for even-numbered minutes is 20.0–20.9–20.0–19.9–20.0–20.9, and for odd-numbered minutes: 20.0–19.9–20.0–20.9–20.0–19.9. The three frequencies also provide a modulation envelope of 100, 900, and 1000 Hz on a VLF whose phase at the beginning of each even-numbered minute has zero offset from Universal Time Coordinates (UTC-GMT). When all three frequencies are used, the arrival phase of the three is unique every 3000 km of great circle distance and varies only with the offset of time and time-rate of the local clock. Thus, if the location is fiixed and known, the time and time-rate can be measured, and if the time and position are known, the great-circle distance to the transmitter and the mean height of the lowermost layer of the ionosphere can be calculated. Time and position are of extreme importance not only for space-flight missions but also for a multitude of terrestrial purposes.

The synchronization of local time with the WWVL signal standard requires a comparison of phase differences between the transmitted signal and the output of a traveling atomic clock such as a rubidium frequency standard (which in turn is calibrated by comparison with cesium primary standards). Unfortunately, many older-style receivers are not designed to take advantage of the three-frequency format of the keyed time-code transmission; however, they can be modified by the addition of a keying circuit which speeds acquisition time and avoids false lock.

The diagram illustrates the essential features of a VLF receiving system, which is seen to consist primarily of a long antenna (which may be buried), an



ordinary superheterodyne receiver having an intermediate frequency of 1000 Hz, a rubidium phase-reference standard, and a phase comparator-recorder to measure accumulated phase error between the reference standard and the received signal. The modification which makes possible operation of the VLF receiving system with a three-frequency signal is the keyer, which has its own power supply, and the clock time-code generator (local clock) which is driven by the rubidium reference oscillator. The only input to the keyer circuit is the time-code generator output; a single control on the panel of the keyer permits selection of the particular frequency which is to be monitored, that is, 19.9, 20.0, or 20.9 kHz.

The keyer circuit is set so that the automatic gain

(continued overleaf)

control (AGC) of the VLF receiver is clamped at the level of the last carrier period, and the antenna is shorted so that no signal enters the receiver. The binary-coded decimal output (BCD) of the time-code generator (local clock) is fed to a logic board within the keyer; depending on the position of the selector control on the panel of the keyer, whenever the BCD time signal from the local clock is coincident with the beginning of the 10-second interval over which the WWVL signal is at the selected frequency, the antenna is unshorted and the AGC is unclamped; at all other intervals, the antenna is shorted and the AGC is clamped. The phase difference between the local clock at a known distance from the transmitter and the WWVL signal is used to reckon the actual local clock time in reference to Universal Time (GMT).

Notes:

1. Details of the keyer circuit are available.
2. The National Bureau of Standards ceased regular scheduled operation of WWVL on June 30, 1972. The time synchronized phase-tracking receiver can, with a minor change in the clock time-code generator-to-keyer interface, use OMEGA VLF broadcasts.
3. Requests for further information may be directed to:

   Technology Utilization Officer
   NASA Pasadena Office
   4800 Oak Grove Drive
   Pasadena, California 91103
   Reference: TSP 73-10275

Patent status:

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning non-exclusive or exclusive license for its commercial development should be addressed to:

NASA Patent Counsel
Mail Code 1
NASA Pasadena Office
4800 Oak Grove Drive
Pasadena, California 91103

Source: Samuel C. Ward of
Caltech/JPL
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